Validation of Biplane Fluoroscopy for Cervical Spine Kinematics

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Introduction

- Traditional kinematic measurement methods offer limited ability to define precise intersegmental motion of the spine.
- Dynamic biplane fluoroscopy has proven to be an accurate, effective, and non-invasive method of quantifying 3D kinematic motion of the spine and other joints [1,2,3].

Objective

The purpose of this study was to validate our dynamic biplane fluoroscopy system's accuracy for assessing cervical spine flexion through CT-based registration with RSA comparison.

Clinical Significance

- Over $80 billion is spent annually on neck and back pain alleviation in the United States [4].
- The majority of neck and back cases are mechanical [5], leading to an interest in understanding how abnormal motion patterns are related to pain and pathology.

Methodology

Data Acquisition

- Tantalum beads (1.6mm) were inserted into the cervical spine vertebral bodies (C4/C5) of a fresh-frozen cadaveric specimen (male, age 62) to facilitate radiostereometric analysis (RSA)
- CT images of the specimen were obtained (0.34x0.34x0.6mm) to generate 3D bone models.
- Dynamic radiographic imaging (70kv, 250mA, 3.5ms, 60Hz) of cervical flexion was acquired on a custom biplanar imaging system (Fig. 1).

Fig. 1: Biplanar fluoroscopy imaging system with 16" image intensifiers equipped with high speed cameras. Note: subject is displayed here, actual data acquisition was performed on a cadaver.

Methodology

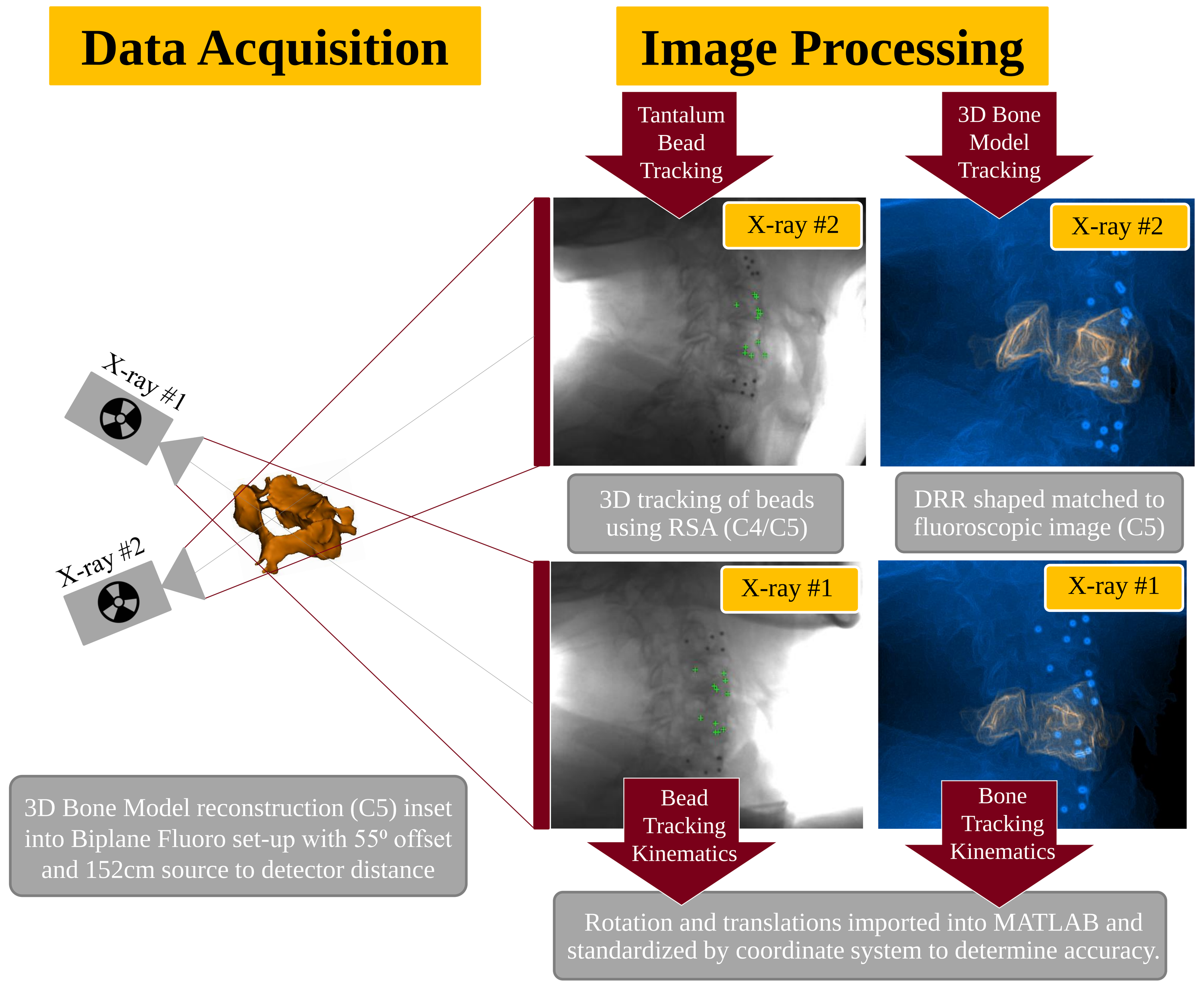

Fig. 2: Data acquisition and image processing workflow diagram

Image Processing

- Three dimensional bone morphologies were created from CT images (Mimics; Materialise).
- The bone models were shape-matched to the dynamic radiographic images (Autoscoper; Brown University).
- Location of tantalum beads were determined using RSA (XMALab; Brown University).
- RMS error, bias, and precision were calculated to examine positional and kinematic differences between CT-reconstruction and RSA values.

Results

Table 1: Rotational accuracy of dynamic biplane fluoroscopy via CT-based registration vs. RSA for cervical spine flexion. Rotation about the Flexion-Extension (FE), Lateral Bending (LB), and Axial Rotation (AR) axes.

	FE (deg)	LB (deg)	AR (deg)
Individual Segment Registration Accuracy			
RMS Error	1.27	0.88	0.97
Bias	-0.34	0.53	-0.65
Precision	1.24	0.66	0.74
Relative Intersegmental Kinematic Accuracy			
RMS Error	1.98	1.56	0.91
Bias	0.77	-0.96	0.18
Precision	1.97	1.02	0.95

Results

Table 2: Translational accuracy of dynamic biplane fluoroscopy via CT-based registration vs. RSA for cervical spine flexion. Translation in Anterior-Posterior (AP), Medial-Lateral (ML), and Superior-Inferior (SI) planes.

	AP (mm)	ML (mm)	SI (mm)
Individual Segment Registration Accuracy			
RMS Error	0.37	0.54	0.53
Bias	0.27	-0.33	0.40
Precision	0.19	0.44	0.36
Relative Intersegmental Kinematic Accuracy			
RMS Error	0.63	0.71	0.50
Bias	-0.22	-0.03	-0.05
Precision	0.58	0.74	0.51

Discussion

- Validation is an essential step to complete for each individual fluoroscopy system to ensure accurate and precise results prior to initiation human subject collection.
- Flexion-extension rotations indicated the highest degree of error, despite being nearest to in-plane motion
- All error was below two degrees (rotation) and one mm (translation) for both registration and kinematic comparisons.

Conclusion

The results affirm that our biplane fluoroscopy system is capable of capturing highly accurate bone tracking and kinematic motion of the cervical spine. This validation assessment will serve as the groundwork to proceed on into human subject collection.

Literature Cited

1. Anderst WJ, et al. *Spine (Phila Pa 1976)* **36**(6), E393-400, 2011.
2. Li G, et al. *J Biomech* **41**(7), 1616-1622, 2008.
3. McDonald CP, et al. *Spine J* **10**, 497-504, 2010.
4. Martin BI, et al. *JAMA* **299**(6), 656-664, 2008.
5. Bigos S, et al. *US Dept of Health and Human Services*, 1994

Acknowledgments

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